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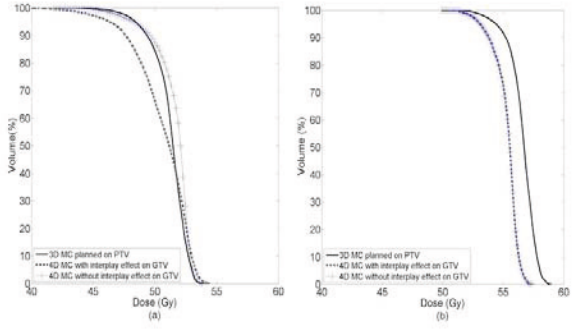
**Purpose/Objective:** To validate the 'mid-position' approach for lung tumor motion management in helical tomotherapy with 4D Monte Carlo planning simulation, in comparison with conventional ITV.
**Materials and Methods:** 8 patients with stage I non-small cell lung cancer (NSCLC) treated by SBRT were included, as well as 6 patients with stage II-III NSCLC treated by Simultaneous Integrated Boost (SIB) and participating in a dose escalation protocol. Prior to treatment, a contrast-enhanced CT (CE-CT) and a 4DCT (for SBRT) or a combined 4D FDG-PET-CT (for SIB) were acquired. The GTV, CTV, and OARs were delineated on the CE-CT according to our clinical protocol. Next, 4D data were used to generate first the ITV and then the MidP volume in its exact time-weighted mean position of the respiratory motion, using a validated Morphon non-rigid registration algorithm. The PTVs were finally drawn according to the margin formula for geometric uncertainties developed by Van Herk et al. and adapted to the specific features of lung tumor tomotherapy. For each patient, two treatments were planned based on margins derived from the ITV and MidP volume. Volumetric and dosimetric parameters, as well as conformity indexes were compared with both strategies. Moreover, dose distributions were computed using a 4D Monte Carlo (MC) model, in order to assess the impact of intra-fraction tumor motion on tumor coverage (quantified by $D_{95}$), with and without the interplay effect.
**Results:** For SBRT and SIB patients, the PTVs defined with the ITV approach were on average 1.2 times larger than those derived from MidP. Consequently, the dose to all the OARs was on average lower when using the MidP. Nonetheless, the planned dose conformity to TVs was identical between both strategies (0,92 ± 0,03 and 0,84 ± 0,05 for DICE and Paddick indexes, respectively). For all SBRT patients, $D_{95}$ to the GTV computed from 4D MC dose distributions complied within 1% of the planning recommendations when using the ITV approach. In contrast, MidP failed to ensure adequate GTV coverage in 3 patients. For one patient, the simulated interplay effect lowered the $D_{95}$ to the GTV by 4.35% compared to the planned dose distribution (Fig a). Although the interplay effect did not affect the two other patients, simulated MC calculations demonstrated significant GTV underdosages, with $D_{95}$ to GTV reduced by 2.16% and 2.61% compared to the planned doses (Fig b). 4D MC computations are ongoing for the SIB group.




**Conclusions:** Compared to the ITV, the MidP strategy significantly reduced the PTV and irradiated volumes in all patients. However, if MidP could safely be applied in helical tomotherapy in most cases, it might lead to insufficient tumor coverage for very small tumors (< 5cc) with large motion (> 10mm). Those particular cases are indeed questioning the fundamental hypothesis underlying the framework of the MidP concept. As SIB treatments are usually delivered to large and centrally located tumors, MidP might allow for a safe reduction of the PTVs and irradiated tissues, although this still needs to be further confirmed.

**PO-0823**
**Intensity modulated treatment plans reoptimization with megavoltage cone beam computed tomography dose**
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**Purpose/Objective:** The megavoltage cone beam computed tomography (MV-CBCT) dose may be considered in the treatment plan prescription dose specially for daily image guided radiation therapy (IGRT) treatments. The dosimetric differences on target volumes and organs at risks obtained optimizing the intensity modulated treatment plan (IMRT) with and without the MV-CBCT were investigated for clinical cases routinely treated.
**Materials and Methods:** A Siemens Medical Solutions, an Artiste™ linear accelerators mounting a MV-CBCT device implemented in Philips Pinnacle3 Treatment Planning System (TPS) was used for this work. Two different type of treatment (head and neck and prostate) performed with daily IGRT-IMRT techniques were enrolled. Twenty prostate carcinomas and twelve head and neck tumors treatment planning were investigated. For each clinical case the dose distribution and the DVH due to IMRT alone (TP1), IMRT plus MV-CBCT dose (TP2), IMRT optimized including MV-CBCT dose (TP3) were examined. $D_{mean}$ and $D_{max}$ were used for target volume comparison and dose volume histograms (DVHs) cut off points for organs at risks (OARs) comparison. The impact of the MV-CBCT protocol used on the integral dose defined as $V_{5Gy}$ was investigated. The CBCT dose calculated was assessed with ionization chamber measurements.
**Results:** The theoretical treatment plan (TP1) compared with the one optimized with the MV CBCT dose (TP3) did not present difference on target dose coverage, while if compared with TP2 (treatment plan added with MV CBCT dose) a mean increase of 4,1% and 3% were obtained for $D_{mean}$ and $D_{max}$ for ORL and prostate treatment respectively. The OARs sparing was worsened in both comparison also if a better sparing is obtained with TP2. For the parotides glands the Dmean percent difference ranged between +8% and 16 % and for the V40Gy of the rectum the percent difference was between 1.5 to 8%. The comparison between the 8 monitor units (MU) CBCT protocol routinely used and the 5 MU and 15 MU protocols showed and increased of the $V_{5GY}$ integral dose between 10 to 52 % and 20 to 66% for ORL and prostate treatment respectively. The decreased of $V_{5GY}$ integral dose obtained with the 5M CBCT protocol ranged between -2 to –7% for for ORL and between -6 to –13% for prostate cases.
**Conclusions:** Prostate and ORL treated with IMRT and IGRT techniques may not be performed without the use of the daily CBCT; it is therefore essential to integrate the MV-CBCT dose in the patient prescription.

**PO-0824**
**Comparison of template-based Elekta VMAT plans with IMRT plans generated by the Varian planning system Eclipse**
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**Purpose/Objective:** VMAT is a complex, arc-based treatment technique for intensity modulated radiation therapy. For different treatment planning systems it has been shown that plan quality is comparable to fixed field IMRT. But achieving acceptable plan quality is often based on experience of the operator. This analysis compares the plan quality of template-based VMAT plans without operator interference against fixed field IMRT plans for Elekta linacs using the Varian TPS Eclipse on a statistical basis for various main tumour regions.
**Materials and Methods:** 181 cases were selected for this study including 40 cervical and endometrial, 73 head and neck, 12 brain, 11 breast and 45 prostate cancer cases. The IMRT plans were developed in clinical routine over the last three years using Eclipse TPS. VMAT plans were generated using a preclinical version of the Eclipse TPS including a VMAT optimizer for Elekta linacs. To standardize the optimizing process, tumour region specific optimizing templates were created. Based on these templates two VMAT plans were generated without interference of the operator: with one full arc (1A) and with two full arcs (2A), resp. one or two partial arcs for breast cancer cases. All plans were evaluated by target coverage, homogeneity and conformity; the organs at risk (OAR) were analysed according to plan objectives such as mean and maximum doses. If one or more objectives were exceeded, a second VMAT plan was created by adapting the optimizing constraints once. All evaluation parameters were averaged over all patients for each region and compared using the Wilcoxon matched-pair signed rank test.
**Results:** For template-based 2A plans in 27 cases out of 181 an exceeding of the objectives for one or more OAR was found, in 13 cases an over- or under-dosage in the PTV. For 1A plans 30 cases showed an exceeding of the OAR objectives, 25 for the target volume coverage. For the additionally modified plans the OAR exceeding was reduced to 23 cases for both 2A and 1A; the over- or under-dosage in the PTV was reduced to 8 cases for 2A and to 17 for 1A. In comparison to the IMRT plans the 1A and 2A plans showed good results concerning the target coverage. Small differences between the considered techniques can be found which depends on the tumour region. A similar behaviour was found for the OAR. But here, the differences between the different techniques and tumour regions show a wider

variation. Detailed values for the PTV and OAR can be found in table 1.

| | | PTV HI | PTV CN | PTV $V_{95\%}$ [%] | Body $D_{mean}$ [Gy] | Bladder $V_{40Gy}$ [%] | Rectum $V_{40Gy}$ [%] | Brainstem $D_{max}$ [Gy] | Spinal cord $D_{max}$ [Gy] | Lung ips $V_{20Gy}$ [%] | Lung contr $V_{20Gy}$ [%] | Lens $D_{max}$ [Gy] | Optic nerve $D_{max}$ [Gy] | Chiasm $D_{max}$ [Gy] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cervical | IMRT | 1.09 | 0.77 | 96.24 | 13.69 | 44.46 | 42.50 | | | | | | | |
| *n=40* | 2 Arcs | 1.09 | 0.83* | 95.06* | 12.91* | 43.03* | 42.84 | | | | | | | |
| | 1 Arc | 1.12* | 0.79 | 92.09* | 12.99* | 43.42 | 42.82 | | | | | | | |
| Prostate | IMRT | 1.09 | 0.78 | 96.70 | 7.29 | 26.42 | 37.61 | | | | | | | |
| *n=45* | 2 Arcs | 1.08 | 0.81* | 96.92* | 6.78* | 25.46 | 41.19* | | | | | | | |
| | 1 Arc | 1.10 | 0.80* | 95.02* | 6.77* | 25.29 | 41.06* | | | | | | | |
| Head Neck | IMRT | 1.13 | 0.72 | 91.39 | 5.36 | | | 35.93 | 35.62 | | | | | |
| *n=73* | 2 Arcs | 1.09* | 0.82* | 95.23* | 5.26 | | | 40.64* | 36.77 | | | | | |
| | 1 Arc | 1.10* | 0.78* | 93.01 | 5.23 | | | 41.65* | 37.90* | | | | | |
| Brain | IMRT | 1.09 | 0.78 | 95.28 | 13.49 | | | 51.62 | | | | 7.34 | 43.21 | 51.12 |
| *n=12* | 2 Arcs | 1.10 | 0.84* | 93.34 | 13.20 | | | 53.99 | | | | 7.28 | 41.40 | 52.15 |
| | 1 Arc | 1.10 | 0.84* | 92.79 | 13.13 | | | 54.33* | | | | 7.22 | 41.11 | 52.76 |
| Breast | IMRT | 1.16 | 0.73 | 87.52 | 9.09 | | | | 16.11 | 19.29 | 1.34 | | | |
| *n=11* | 2 Arcs | 1.13* | 0.74 | 90.30* | 9.61 | | | | 17.18 | 18.03 | 1.43 | | | |
| | 1 Arc | 1.18* | 0.72 | 85.30* | 9.40 | | | | 18.16 | 20.09 | 1.41 | | | |

*p < 0.05 for Wilcoxon matched-pair signed rank test 2 Arcs vs IMRT resp. 1Arc vs IMRT

Table 1: mean values of plan parameters for each tumour region for the three considered techniques; HI = $D_{5\%}/D_{95\%}$; CN by van't Riet

**Conclusions:** The Eclipse planning system is able to achieve a comparable plan quality for Elekta VMAT delivery technique to that of fixed field IMRT in terms of target coverage and critical structure sparing using optimizing templates without operator interference. Plans with 2 arcs show less exceeding of the objectives than plans with 1 arc. In the VMAT cases where the objectives are not met, adapting the optimizing parameters once results in an improvement of the target coverage and OAR sparing.

**PO-0825**

**Rectal dose limiting efficacy assessment of an implantable biodegradable device for prostate cancer radiotherapy**

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**Purpose/Objective:** Many indications suggest that a dose escalation in prostate carcinoma treatment could improve the disease local control. Several methods are developed to reduce the rectal volume involved in high doses since rectal toxicity is one of main aspects limiting the prescribed dose. One possible strategy is to insert between rectum and prostate walls a little balloon. This study aims to assess the efficacy of this experimental device in reducing rectal dose in prostate EBRT.
**Materials and Methods:** 9 patients with prostate carcinoma were recruited in 2010 at the Oncology Institute of Veneto (Padova, Italy) for a 'one-arm' multicenter study to evaluate the use of a biodegradable implantable balloon in term of efficacy and safety. The balloon is made of co-polymer Poly(L-lactide-co-ε-caprolactone). After the implantation between prostate and rectum anterior wall the balloon is filled with physiological solution. It remains in situ at least the whole radiation treatment time. Every patient had a CT scan (CT1) before the implantation and one after (CT2). The last one was used for plan optimization. A mean of 4 CT scans were acquired for every patient during treatment to assess the stability of the device. 3 treatment plans were calculated on CT1 and CT2:
1. a 6 fields standard 3DCRT (the one actually delivered).
2. a 7 fields 3DCRT technique.
3. a 7 fields IMRT.
The prescribed dose was D95=78 Gy in 39 fractions. D50, V75, V70, V65, V60, V50 and V78 rectum DVH points were evaluated. QUANTEC dose limits were also verified. 3DCRT plans calculated on CT2 were compared with the IMRT plans calculated on CT1 to evaluate the device efficacy instead a highly conformance technique. A t-test was used to evaluate the statistic significance between plans.
**Results:** Dose analysis shows implant efficacy for both 6 and 7 fields 3DCRT techniques. DVHs comparison shows a 40 % and 55% mean reduction in V50 and V60 values. D50 decreases from 54,95 Gy to 44,26 Gy for the 6 fields 3DCRT with a reduction of 18% (p <= 0.01) and from 49.6 Gy to 38.8 Gy for the 7 fields 3DCRT with a reduction of 21% (p <= 0.01). Balloon allows the right QUANTEC dose-volume constraints in 7 out of 9 patients. A significant reduction of V78 mean value is observed, passing from a 4.0 cc to 1.2 cc. IMRT technique shows insignificant differences between cases. D50 is reduced of 3% while V78 remains about 1cc for both cases. QUANTEC limits are independently reached using IMRT. Dose comparison between 3DCRT techniques with balloon and IMRT technique without doesn't show a clear advantage in using the experimental device.
**Conclusions:** Our dosimetric study clearly shows the efficacy of the implantable device reducing rectal dose in case of 3DCRT techniques. IMRT technique with no device is comparable with the 3DCRT with device.

**PO-0826**

**Comparison of flattened and filter free VMAT with different MLCs in delivery of SRS**

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**Purpose/Objective:** To compare plan quality in terms of dosimetric homogeneity, target conformity, organ-at-risk (OAR) sparing, monitor unit (MU) usage, and beam-on time for eleven stereotactic radiosurgery patients using RapidArc™ volumetric- modulated arctherapy (VMAT) with both standard and flattening filter free modes. Plans where calculated with both a standard120 leaf MLC and a HD120 MLC.
**Materials and Methods:** Eleven patients with one or more brain metastases underwent computed tomography simulation. Treatment planning was performed using Varian Eclipse ™ v10.0.39 to generate four 2-arc RapidArc plans.Each patient was planned with FFF and flattened mode with both a standard and high definition MLC. All plans were calculated to deliver the same mean dose tothe PTV. Plans were created with dose control tuning structures surrounding targets to maximize conformity and dose gradient. Dosimetric parameters used for target analysis were RTOG conformity index (CIRTOG), homogeneity index (HIRTOG), inverse Paddick Conformity Index(PCI) and D5-D95. OAR sparing was analyzed in terms of Dmax and D10cc for brain. Treatment delivery was evaluated based on measured beam-on times delivered on a Varian Truebeam, Varian Truebeam STx and Varian Clinac iX linear accelerators.
**Results:** Dosimetric conformity, homogeneity, and OAR sparing were comparable when using the HDMLC irrespective of mode for all patients. The Paddick Conformity Index was inferior for the standard MLC plans than the HDMLC with the mean decreasing from 4.3(±1.2) to 3.8(± 0.7). The PTV homogeneity index was inferior for the standard MLC than the HDMLC plans, decreasing from 3.3(± 0.8) to 2.4(± 0.7). Mean beam-on times for FFF mode and flattened mode were 3(±0.7) and 12(±2.4) minutes, respectively. Mean MUs were 6760 and 7015, respectively.
**Conclusions:** Dosimetric conformity, homogeneity, and OAR sparing were similar when planned with a HDMLC. There was some reduction in conformality when planned with a standard MLC. Conformality was independent of treatment mode. The use of FFF resulted in substantially less beam-on time and fewer MUs than standard mode. The rapid delivery of SRS with an HDMLC and FFF improved workflow on the linac and limited the potential for intra-fraction organ and patient motion, which can cause dosimetric errors

**PO-0827**

**Elekta AgilityTM FFF for Lung VMAT SABR.**

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**Purpose/Objective:** It has previously been reported that VMAT reduces the overall treatment time for lung SABR compared to conformal therapy techniques. This study investigates whether the increased dose-rate available with Flattening-Filter Free (FFF) beams can be used to further decrease delivery times. An analysis was also made of FFF plan quality relative to standard (flattened-beam) plans.
**Materials and Methods:** 5 patients were planned for lung SABR with a dose of 55Gy in 5 fractions. VMAT plans with flattened 6MV beams(6X) and flattening filter free (6XFFF) were compared. The 6XFFF beam energy was tuned so that dose was matched to the flattened 6X beam energy at a depth of 10cm in water. All planning was performed with Monaco v3.3*[1] for delivery on a Synergy*[1] Linac with Agility™ head. An isocentre positioned at the patient mid-line was used for all plans. Treatment deliveries were verified using the Delta4*[2] phantom and chamber measurements in a CIRS*[3] lung phantom. Plans were compared in terms of measured delivery time, gamma index and PTV point dose.
**Results:** Plans produced with both 6X and 6XFFF had comparable plan quality (Table 1) and were produced in a similar time-frame.The VMAT prescription class solution used clinically for 6X treatments did not require alteration when planned with 6XFFF. Dose deliveries for both